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Robert A. Taft Sanitary Engineering Company
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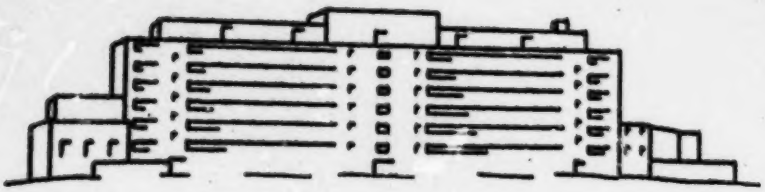

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TREATMENT OF WASTES FROM COFFEE PROCESSING IN COSTA RICA

by

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and

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Although little is known in the United States about the industrial wastes resulting from the processing of coffee cherries, it is an important problem in the coffee producing countries of Central and South America.

Water is a scarce commodity in many of these areas and streams are being subjected to a damage from which they cannot recover. Wastes are sometimes discharged into dry channels where decomposition occurs and an odor nuisance develops, affecting those living in the vicinity. Since there was a desire to determine the feasibility of the treatment of these wastes in stabilization ponds in the country of Costa Rica, a preliminary study was made to learn more about the characteristics of the coffee wastes. Tentative calculations were then made concerning the size of stabilization ponds necessary for these wastes. A brief outline of the information collected is summarized on the following pages.

THE PROCESS

The various steps during the processing of coffee cherries are listed below. A flow diagram showing the steps, along with points of water use and waste sources, is presented in Figure 1.

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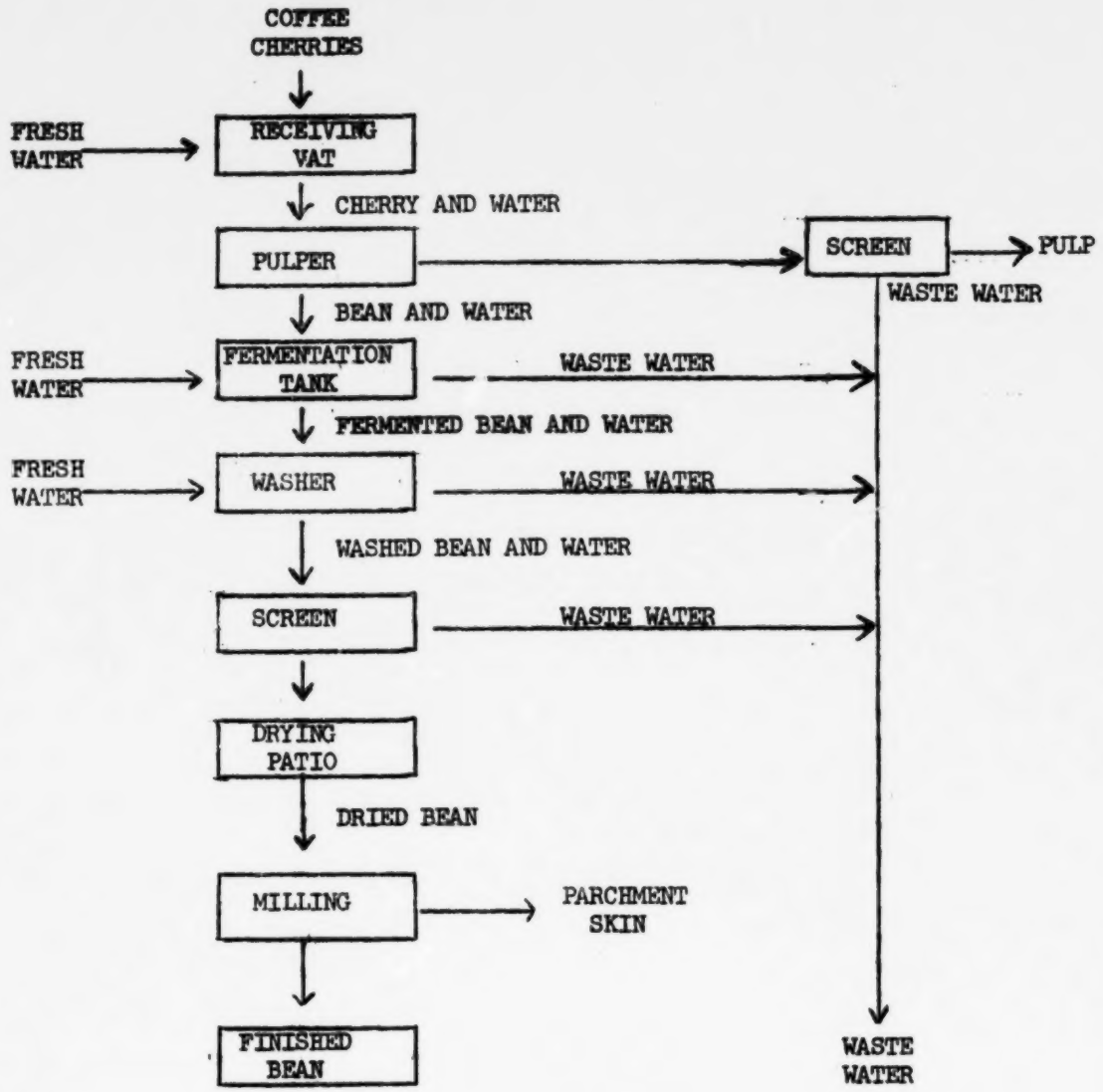

FIGURE 1 - FLOW DIAGRAM OF TYPICAL COFFEE WASHING MILL

1. The coffee cherry is dumped into a receiving vat from which it is conveyed to the pulpers by water.
2. During this conveyance, stones, etc. are separated by traps, and "floaters", the unsound cherries, are diverted to separate pulpers.
3. The pulper removes the skin and a large portion of the flesh from the coffee bean.
4. The hulled bean is then transported by water to a fermentation vat where it is allowed to remain and ferment in a moist state, the excess water being drained off after conveyance, and reused if desired. The period of fermentation may be as little as 12 hours or as much as 2 days, depending on fermentation conditions. Fermentation of the bean is required before all the

flesh of the cherry can be satisfactorily removed from the parchment which immediately surrounds the silver skin of the coffee bean. The protopectin in the flesh is insoluble and cannot be washed or scrubbed off the parchment. The bean cannot be satisfactorily dried before damaging fermentation of the bean itself occurs, as long as the protopectin adheres

to the tough parchment. The fermentation process enables the bean to be dried in a clean parchment which guarantees its quality.

5. The fermented bean is then washed, hydraulically classified, and conveyed to the drying patios, again by water. The beans are screened from the water and spread out to dry in the sun for several days. Sometimes mechanical driers are used subsequent to sun drying.
6. When the coffee has dried sufficiently to insure color and flavor, it is milled to remove the parchment. The coffee bean is then graded, sacked, and shipped to the markets.

USE OF WATER IN COFFEE INDUSTRY

The principal uses of water in the coffee mills are as follows:

a. To transport the coffee to the pulpers
b. To transport the pulp to a hopper or pile
c. To transport the beans to the fermentation vats
d. To wash the fermented bean
e. To transport the fermented bean to the drying patio
f. Miscellaneous operations:

Traps for stones, etc.
Separation of "floaters"
Hydraulic classification of beans
Boiler water

The water requirement is in the order of 260 gallons per 100 lbs. (quintal) of finished coffee, in those plants where the water is used only once. This quantity is reduced to 100 gallons per quintal of finished coffee in those plants which recirculate as much water as possible.

CHARACTERISTICS OF THE WASTES

The main wastes from coffee mills may be listed as follows:

1. Pulp
2. Pulping water
3. Fermentation wash water
4. Parchment

These wastes result from the processing of the coffee cherry, which has the following composition: (1)

COMPOUNDS	MINIMUM, %	MAXIMUM, %	AVERAGE, %
Water	6	16	9-12
Ash	3	4.5	4
Nitrogen	8	14	12
Cellulose	10	35	24
Sugars	6	11	9
Dextrin	-	-	1- 1.5
Fat	10	14	12
Caffetannic acid	6	10	8- 9
Caffeine	0.6	2.25	0.7- 1.3
Nitrogen-free extract	12	33	18
Essential oil	-	-	0.7
Water-soluble material	20	36	25.3
Theophylline	Trace	-	-
Theobromine	Trace	-	-

The pulp is the most potentially damaging waste from the mills, but it is generally recovered and used for fuel or fertilizer. When the fresh pulp is stored in open piles its sugar is attractive to flies and a bad nuisance develops. When the pulp begins to ferment, a foul, repulsive odor is emanated. There is no fly breeding in the pulp, probably because of the acid nature of its decomposition.

The pulping water contains a relatively high amount of settleable solids, and as it contains sugars and other soluble materials, it is a large contributor to stream pollution.

The fermentation wastes are very bulky with colloidal gels of pectin and the other products removed from the coffee parchment by fermentation. The strength of this waste is small when compared with that of the pulping water, and its products of decomposition are relatively stable and inoffensive.

The parchment from the dry milling of the dried bean has no sanitary significance. It is nearly pure cellulose, and is generally used for fuel in the steam boilers that power the mills.

In a study made in El Salvador,(1) samples were taken of the wastes at three plants. As each plant used different proportions of water, the results of the examinations varied considerably.

The range of values found are as follows:

WASTES	5-day 20°C-BOD, ppm	Settleable solids, ml. per liter	Total solids, ppm	Suspended Solids ppm
Pulp	47,000	-	-	-
Fermentation wastes	1,250-2,220	600-700	4,260	2,060
Pulping wastes	1,800-2,920	60-127	4,960	848
Combined pulp and fermentation wastes	6,150-134,000	160	3,220	-

These analyses were made at the end of the milling season, and the plants were not operated at capacity. The above figures, therefore, are low compared to what may be expected when the peak of the processing is reached, and more cherries are milled per volume of water.

The results are more significant and consistent when calculated on a unit basis, and they more nearly approach the strengths expected when the mills are operating at capacity.

Lbs. of 5-day, 20° C. BOD per quintal of coffee cherry milled:

Average, pulping water	0.56
Average, fermentation water	0.08

Disregarding the pulp, which is usually removed, the expected 5-day BOD load per quintal of coffee cherries milled would be the sum of the two other components of the waste or a total of 0.64 pounds.

In another study in El Salvador the characteristics of a mixture of 50% pulping water and 50% fermentation water were listed.[2] These are as follows:

	Min.	Max.	Mean
BOD (5-day), ppm	2,500	8,000	4,250
pH	4.3	4.7	4.5
Turbidity, ppm	1,500	2,500	2,250
Suspended solids, ppm	530	810	640
Total solids, ppm	6,800	7,240	7,050

In actual practice the fermentation waste volume usually is larger than waste from the depulping operation.

METHOD OF TREATMENT OR DISPOSAL

Pulp

Pulp is valuable as fuel or fertilizer, and for this reason, it is convenient to remove it from the conveying water by screens, and then handle it in one of the following ways:

1. Immediately haul by trucks or carts to the farms where it is plowed into the ground.

2. Immediately dry upon patios and use for fuel. Filter presses have been used very satisfactorily to yield a cake that may be burned after a few hours drying. Dried pulp is also used for fertilizer.

3. When there are no facilities to carry the pulp away immediately, it may be stored in a pile; but the fresh pulp, because of its sugar content, creates a fly nuisance. Also, if it is allowed to remain in a moist condition, fermentation occurs which yields foul odors. Flies and odors are sometimes partially controlled by sprinkling lime over the pile. After the milling season the pulp is usually taken to the farms where it is used as fertilizer.

One analysis made (1) on dried pulp is as follows:

	Content (Per cent)
Protein	1.30
Fiber	19.70
Nitrogen-free Extract	50.10
Ash	9.00

The value of pulp as fuel and fertilizer is well established but the most important reason for removing the pulp from the wastes is to reduce the possibility of a serious pollution problem. Sludge deposits would likely result, and with a BOD of approximately 47,000 ppm a severe demand would be placed on the oxygen resources of the stream.

Pulp silage has been suggested for animal feed, and controlled feeding experiments have been conducted in some Central American farms.

Parchment

The parchment is nearly pure cellulose and has no sanitary significance. It may be used as a fuel.

Liquid Wastes

The use of liquid wastes for irrigation has been overlooked.(1) Observations of dry stream channels, which have conducted wastes that have had reasonable sedimentation, show no evidence that the waste is toxic to plant life. Damage has only been observed where plant life is subjected to wastes, high in solids, that have been ponded. This method of disposal would be practicable and beneficial in those areas where contour irrigation ditches could be utilized. Lime could be added if needed for pH control, and its application would enhance the value of the waste for land use.

An experimental treatment plant was operated in 1947 in one of the largest coffee plantations in El Salvador (2) producing 5,000 quintals per day. The pilot plant comprised a retention lagoon of 4,860 gallons; sedimentation tank (plain) of 425 gallons; a stone filter 16 square feet in area and 6 feet deep; a final detention tank of 306 gallons; and a 2-inch centrifugal pump driven by a gasoline engine. To develop colonies of bacteria in the filter, wastes were circulated through it daily for a month before the test began.

The wastes were run into the sedimentation tank. When chemical precipitation was used, the coagulant was added in the sedimentation tank and mixed by hand. The mixture was then held for one hour in the sedimentation tank and a predetermined volume (based on the filter loading selected and number of recirculations per hour) was siphoned into the detention tank.

Samples of filter effluent were taken at 2, 4 and 6 hours, but circulation through the filter continued 12 to 16 hours and sometimes 24 hours longer. All samples were settled one-half hour before analysis. The analyses made were 5-day BOD, pH, turbidity and total solids.

General results of study were:

a. Biological treatment with recirculation through stone filters was effective. The number of recirculations varied

between 2 and 15 per hour. Reduction of BOD varied between 54 and 82 percent after 2 hours; 64 to 86 percent after 4 hours and 76 to 92 percent after 6 hours. The best results were obtained with 10 recirculations per hour and a filter loading of 60 million gallons per acre per day.

b. One hour sedimentation produced very little reduction in BOD, usually 16 to 29 percent.

The tests proved that biological filters with high rates of application and recirculation was the best method, but efficiency was less with depulping wastes than with fermentation wastes.

STABILIZATION PONDS FOR LIQUID WASTES

As discussed previously, the pulp is first removed from the waste so that this large quantity of solids does not enter the stabilization pond.

A tentative design of stabilization ponds for liquid wastes from coffee processing has been made.

Data

a. 0.64 lbs. BOD in the liquid wastes from a quintal of coffee cherries.

b. 100 lbs. BOD per acre per day is the permissible loading for a stabilization pond in tropical countries.

c. Q = 200 gallons per quintal of finished coffee.

d. Assume 40% of the coffee cherry weight is weight of beans.

e. Average temperature of air 25° C.

f. Average temperature of water 20° C.

g. Wind velocity 10 miles per hour.

h. Percolation must be less than 1/8" per day.

Calculations

Basis: 100 quintales of finished coffee per day.

a. Area of the pond in acres:

$$\frac{\text{100 lbs. BOD/acre/day}}{\text{0.64 lbs. BOD/quintal}} = 156 \text{ quintales of coffee cherries per acre.}$$

156 x 0.40 = 62 quintales of finished coffee per acre.

$$\frac{\text{100 quintales}}{\text{62 quintales/acre}} = 1.61 \text{ acres}$$

b. Volume of water:

$Q = 100 \times 200 = 20{,}000$ gallons

c. Percolation:

$$Q_p = \frac{1 \times 1.61 \times 43{,}560 \times 7.48}{8 \times 12} = 5{,}500 \text{ gallons}$$

d. Evaporation:

Meyer formula: $Em = C\,(V - v)\,[1 + (W/K)]$

Em = evaporation in inches per month

V = vapor pressure in inches of mercury at air temperature

v = vapor pressure in inches of mercury at water temperature

W = wind velocity in miles per hour

K = constant = 10

C = constant = 15

W = 10

$v = 17.5/25.4 = 0.69$

$V = 23.8/25.4 = 0.94$

$Em = 15(0.25)\,(2) = 7.5$ inches per month

Ed = 0.25 inches per day

$$Q_E = \frac{0.25 \times 1.61 \times 43{,}560 \times 7.48}{12} = 11{,}000 \text{ gallons per day.}$$

e. Pond discharge during the milling season:

$Q_D = Q - (Q_p + Q_E) = 20{,}000 - (5{,}500 + 11{,}000) = 3{,}500$ gallons per day.

f. Detention period:

assume an operating depth of 3 feet

Volume per acre = 43,560 x 3 x 7.48 = 980,000 gallons

Volume per 1.61 acres = 1.61 x 980,000 = 1,580,000 gallons.

Minimum detention period = $\frac{1,580,000}{20,000}$ = 79 days assuming no evaporation or seepage.

Nutrients for Algae

Available information indicates that there is sufficient nitrogen, but there may be an insufficient amount of phosphates to support algal growth. Therefore, it may be necessary to add supplemental phosphates. It is possible that sewage from the farm houses could be added to the pond and thus provide the necessary phosphate.

Calculation of phosphate requirements:

1 lb. phosphorus per 150 lbs. BOD(3)

64 lbs. BOD per 100 quintales of coffee cherries

64/150 = 0.43 lb. phosphorus per 100 quintales of coffee cherries

0.43/0.40 = 1 lb. phosphorus per 100 quintales of finished coffee

1 x 96/32 = 3 lbs. phosphate per 100 quintales of finished coffee

Sewage contains about 6 ppm soluble phosphorus(4)

0.02 x 8.34 x 6 = 1.0 lb. phosphorus in 20,000 gallons sewage, the same volume as coffee wastes. Since sewage usually contains sufficient phosphorus, it is expected that the phosphorus in the coffee wastes would be adequate if brought up to the same concentration as in sewage.

pH

The pH of the combined wastes is approximately 4.5. The wastes must be neutralized before entering the pond. Since lime is readily available in Costa Rica, it may be used for neutralization.

During the months outside of the milling season it may be necessary to have a source of water for the pond that compensates for the water losses by evaporation and seepage, if the rainfall is not sufficient to keep the pond at the operating level. If this is not done, there may be a mosquito problem during the time that the pond level gradually decreases.

SUMMARY OF WORKING CONSIDERATIONS

1. Obtain chemical analysis of combined plant wastes after separation of the pulp. Analyses should be made for BOD, pH, phosphate, total nitrogen, and suspended solids as a minimum. Other analyses may be made to suit specific needs.
2. The waste flow
3. The ratio of the weight of coffee beans (seeds) to total weight of cherry.
4. Soil conditions and seepage rates.
5. Best methods to separate pulp
6. Best method for pulp and parchment disposal.

7. Light penetration thrcugh coffee wastes.
8. Evaporation rates.
9. Determine whether it is more satisfactory to operate ponds seasonally and allow to dry up during non-producing season or keep liquid in the pond the year around.
10. Economic considerations.

This is not intended to be a complete list. Others may arise when the actual problem is encountered.

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